Intermediate Development Outcomes for CRP Grain Legumes

Grain Legumes: Leveraging legumes to combat poverty, hunger, malnutrition and environmental degradation
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Introduction
The CGIAR Research Program on Grain Legumes (GrainLegumes) combines and coordinates research-for-development activities of eleven principal partners: four CGIAR centers (ICRISAT-lead center, CIAT, ICARDA and IITA), a CGIAR Challenge Program (Generation), four major national agricultural research systems (EIAR, Ethiopia; Embrapa-Brazil, GDAR-Turkey and ICAR-India) and the two USAID-supported legume Cooperative Research Support Programs. All of whom are leaders in grain legume research.

The broad objectives addressed by GrainLegumes are to increase production, sales, consumption and the beneficial contribution of grain legumes to agricultural systems and so to reduce poverty, hunger, malnutrition of smallholder farmers and their households, while improving the health of both the urban and rural population which will increasingly depend on these foods.

The success of the project would be characterised in three ways (i) approximately 20% of crop area as legumes and concomitantly reduced demand for inputs (ii) balanced nutrition for consumers from the combination of legumes & cereals, including vegetable legumes and (iii) that these together will provide stable income to smallholders.

Rationale
Agriculture has become dependent on a major change to the nitrogen cycle that began in the 1940s (Donald et al. 2010 Science 330: 192-196; Holtgrieve et al 2011 Science 334: 1545-1548; Elser 2011 Science 334: 1504-1505), but initially it became successful in those locations where a grain legume was domesticated, so providing balanced nutrition as well as soil fertility (Diamond J. 2002 Nature 418: 700-707). Grain legumes provide protein rich seeds; typically these have two to three times the protein content of cereals. Like cereals their amino acid composition is not ideal for an exclusive diet but, taken together, these two are complementary. Grain legume protein is accompanied by slowly digestible starch, or oil, depending on the species. There are many minor components of these seeds that also have dietary utility. These crops can also provide fresh green vegetables, animal feed or fodder and even fuel for cooking. Grain legume crops fix atmospheric nitrogen as a consequence of a symbiosis with certain root bacteria; this obviates the need for nitrogen fertilizer during their growth and also provides biologically available nitrogen and carbon in the soil to following or companion crops with minimal greenhouse gas production. These crops are diverse; among them soybean and groundnut are major commodities. Soybean is the world’s third largest crop after rice and wheat; FAO figures suggest that soybean and groundnut have a combined global value almost equal to that of wheat.

The environmental impact of a grain legume based meal is about half of that of a meat based meal of an equivalent nutritional value. This means that grain legumes have great potential in contributing to the System Level Outcomes of Improved Food Security and Enhanced Environmental Sustainability while contributing to Improved Nutrition and Health in the face of increasing population pressure and climate instability. A corollary of the low environmental footprint of legume crops is their relatively low cost with respect to foods based on animal products. The high nutritional value and low cost of legumes as food makes them especially attractive for low income households. This has tended to stigmatise the consumption of legumes in non-vegetarian cultures, although there is a growing awareness of their dietary and nutritional value among those for whom meat eating is not seen as a necessary correlate of status.
The CGIAR Research Program on Grain Legumes (GrainLegumes) is focused on eight major grain legume crops, and mungbean will be proposed to be included as a ninth for the second phase of the program. The basic objective is to deploy recent advances in ICT, and genomics to ensure that these crops fit well in cropping systems in our target regions in such a way as to facilitate a good income for smallholder farmers. The development of Intermediate Development Outcomes represents a tool for priority setting, as well as monitoring and evaluating the progress of our activities towards the broad System Level Outcomes. The Intermediate Development Outcomes provide a way to structure our target setting and to balance efforts within the programme as a whole.

The programme operates in several regions and across eight crops:
- South and Southeast Asia (SSEA)  
  chickpea, groundnut, pigeonpea, lentil
- Sub-Saharan Africa (SSA)  
  groundnut, cowpea, common bean, soybean, faba bean, pigeonpea, chickpea
- Central and Western Asia and North Africa (CWANA)  
  chickpea, lentil, faba bean
- Latin America and the Caribbean (LAC)  
  common bean

The programme is organised into eight ‘Product Lines’ representing thematic approaches rather than according to crop or region, this is in order to benefit from cross institutional collaboration and to exploit the common underlying similarities in agronomy, place in the market, biology and genetics of these crops.

The product lines are:
- PL1 Drought & low-P tolerant common bean, cowpea & soybean
- PL2 Heat tolerant chickpea, common bean, faba bean and lentil
- PL3 Short-duration, drought tolerant & aflatoxin-free groundnut
- PL4 High nitrogen-fixing chickpea, common bean, faba bean and soybean
- PL5 Insect-smart chickpea, cowpea, and pigeonpea production systems
- PL6 Extra-early maturing chickpea and lentil varieties
- PL7 Herbicide tolerant machine-harvestable chickpea, faba bean and lentil varieties
- PL8 Pigeonpea hybrid and management practices

Each product line (PL) has been selected because prior analysis has indicated that each has the potential to introduce major changes (game changers) to the smallholder farmers and consumers who are the intended beneficiaries of GrainLegumes (see http://grainlegumes.cgiar.org/).

The Research Framework
The following five Strategic Components (SCs) contribute to advancing Grain Legumes objectives of improving the production, sales, and consumption of grain legumes. Targets are described with respect to these components within each product line an according to IDO.

SC 1 Analyzing demand and setting research priorities
  Identify priority research and development needs ranging from farmers, seed sellers, processors, and marketers to consumers and policymakers.

SC 2 Developing productive varieties and management practices
Accelerate the development of more productive and nutritious legumes varieties and crop and pest management practices for resilient cropping systems of smallholder farmers.

**SC 3** *Facilitating legume seed and technology delivery systems*
Develop and facilitate efficient legume seed production and technology delivery systems for smallholder farmers.

**SC 4** *Enhancing post-harvest processing and market opportunities*
Enhance grain legumes value additions, and social and environmental benefits captured by the poor worldwide, especially women.

**SC 5** *Fostering innovation and managing knowledge*
Partnerships, capacities, and knowledge sharing to enhance grain legume R4D impacts.

These strategic components were also important in allowing us to set priorities that are also location specific.

**Impact Pathways and Theory of Change**
As a ‘commodity’ research programme GrainLegumes delivers its research outputs at several levels, notably through seed based technologies, agronomic interventions and market based methods.

*Seed based technologies*
These technologies interact with the value chain at several levels; the most obvious is the development of varieties. Secondly there is the utility of these varieties as represented by their primary function in nutrition and a secondary role in the farm system, improving soil fertility or providing animal feed or fodder. All require intervention through breeding, and thus have long lag times for the intervention to achieve an outcome.

The cycle of breeding breaks down into several steps: (i) trait evaluation (physiological modelling, comparative biology, screening extant genotypes), (ii) allele discovery (this could in principle include transgenics), (iii) introgression to adapted backgrounds (pre-breeding), (iv) breeding and selection, (v) seed bulking and variety testing, followed by trialling and registration and (vi) variety distribution.

Each of these steps is a multi-year process, and the overall strategy is often conceived as linear, so there appears to be a disconnect between the early and late stages, but this is not really the case because the process is cyclical, and iterative, with connections that can be construed either as feedback or feed forward loops. The breeders’ lines and varieties provide raw materials for early steps in the process and their performance or constraints sets priorities for trait evaluation.

Seed based technologies are strongly represented in all our product lines.

Within GrainLegumes we seek to add value to the activities of smallholder farmers, notably women, and also to the consumers of their products. This represents a sieve for priority setting in relation to target traits and is discussed under ‘market based methods’ below.
Agronomic interventions
The way in which farmers manage their cultivation has immediate and direct impact on their livelihood – the crop can fail or it can produce effectively. We note that yield increase per se may not have a direct benefit to the producer because it reduces market price (see market based methods) nevertheless this remains a target because of its impact on consumers who are also target beneficiaries.

Agronomic practice has the potential to change outcomes for smallholders in a the short term, so these are attractive targets for improvement; however they often require appropriate varieties for full implementation and so there is an interaction between agronomic interventions and seed based technologies.

Agronomic interventions (as opposed to breeding varieties that overcome agronomic constraints) are especially strong in the product lines:
- PL4 High nitrogen-fixing chickpea, common bean, faba bean and soybean
- PL5 Insect-smart chickpea, cowpea, and pigeonpea production systems
Within
- PL7 Herbicide tolerant machine-harvestable chickpea, faba bean and lentil varieties
the aim is to generate and disseminate varieties that can minimise labour costs and time investment (especially of women) together with aggregative approaches that can increase return to small holder farmers.

Market based methods
Markets include the generation production of seed for farmers as well as the sale of the farmers’ produce, and thus includes studies of seed systems - how seeds reach the smallholder farmers and their certification as to provenance and phytosanitary quality as well as quality in terms of germination rate and vigour of establishment. These considerations include gender relations in the seed system as a whole.
The quality of produced seed, in relation to seed contamination is especially a focus in the product lines:
- PL3 Short-duration, drought tolerant & aflatoxin-free groundnut
- PL5 Insect-smart chickpea, cowpea, and pigeonpea production systems
Other product lines relate to the quality of seed for market, their nutritional value, and overall production. The hybrid seed in PL8 has important interactions with the seed system and the improvement of productivity that acts synergistically.

Intermediate Development Outcomes and System Level Outcomes
The five Intermediate Development Outcomes of the Grain Legumes CGIAR Research Program are:

- **IDO1 Food Security**: Improved and stable access to grain legumes by urban and rural poor
- **IDO2 Income**: Increased and more equitable income from grain legumes by low income value chain actors, especially women
- **IDO3 Nutrition & Health**: Increased consumption of healthy grain legumes and products by the poor for a more balanced and nutritious diet, especially among nutritionally vulnerable women and children
- **IDO4 Productivity**: Improved productivity of farming systems, especially among smallholder farmers
- **IDO5 Environment**: Minimized adverse environmental effects of increased production and intensification of grain legumes
The diagram (right) illustrates the relationship between these five IDOs and the four CGIAR-wide System Level Outcomes. The relationship is one to many, because single development outcomes can have multiple consequences. For example, improving the productivity of rice/chickpea cropping systems by reducing the number of days to maturity for chickpea means that a chickpea crop can fit into the window between two successive rice crops. This has several consequences; the first is an overall gain in productivity because of the extra crop; this generates additional income and so contributes to reduced rural poverty. Secondly the addition of a legume crop generates a protein rich grain that complements the nutritional value of a cereal and so increases the nutritional value of the cereal as well as providing value from the crop itself, thus contributing to improved food security. Thirdly the inclusion of a legume crop leads to the inclusion of additional soil organic matter and especially biologically available nitrogen. This reduces the requirement for exogenously added mineral nitrogen fertilizer in addition to the usual value of a break crop. The inclusion of a grain legume crop therefore contributes to enhanced environmental sustainability.

Within each product line there is a direct connection with each IDO, and each of these connections is associated with a theory of change, and a set of targets that can be used to monitor progress towards the intended outcome. This is a complex interconnection and set of causalities that can be described only in broad outline within a reasonable amount of space.

**Targets**

The Intermediate Development Outcomes are broad, and each could be enhanced by activities within any PLC. For this reason alone it would be necessary to develop a set of targets for the monitoring and evaluation of the Product Line. Our current view of the targets necessary in each product line are given below.

**IDO1 Food Security: Improved and stable access to grain legumes by urban and rural poor**

- An additional 1.6 million tons of common beans are available annually in Latin America, and 1.3 million tons in Africa, derived in part from an additional 500,000 hectares in heat prone areas, and an additional 500,000 hectares of climbing beans
- At least 10% increase in cowpea production resulting in higher supply of grains to the market and ultimately consumers
- At least 550,000 ha area in new niches brought into cultivation of chickpea, faba bean, lentil and bean by growing heat tolerant varieties
- At least 15% increase in groundnut supply at household level in target areas in Malawi, Mozambique, Tanzania and Uganda and 10-15% in Nigeria, Mali, Senegal and Niger
- Decrease in grain legume price volatility/variability by at least 3-5% in the target regions in India, Malawi, Mozambique, Tanzania, Uganda, Nigeria, Mali, Senegal and Niger; and 2% in Egypt, Ethiopia, Morocco, Syria, Turkey and Iran
- About 1 million households growing an additional crop of short-duration chickpea/lentil in rice fallows and rice-rice systems
- Decline in real price of pigeonpea by at least 10% in target regions
**IDO2**  *Income: Increased and more equitable income from grain legumes by low income value chain actors, especially women*

- Income from common bean sales increases by at least USD 250 million in Latin America and USD 300 million in Africa
- 10-15% increase in income of 1 million households from growing drought and low-P tolerant cowpea varieties
- 15-20% increase in income for at least 2.5 million households, of which 30% income earned by women, by growing heat tolerant varieties of chickpea, faba bean and lentil
- 10-15% increase in income from groundnut for 1 million households across India and Vietnam
- 10-20% reduction in labour requirement for women by cultivating short duration improved groundnut in India, Vietnam, Malawi, Mozambique, Tanzania and Uganda, Burkina Faso, Ghana, Mali, Senegal, Nigeria and Niger
- 10-20% increase in groundnut export due to reduced aflatoxin contamination in India, Vietnam; 15-20% in Malawi, Mozambique, Tanzania and Uganda; and up to 10% in Burkina Faso, Ghana, in Nigeria, Mali, Senegal and Niger
- 10% increase in income from groundnut in 150,000 households in Burkina Faso, Ghana, Nigeria, Senegal, Mali; and 15-20% increase in income from groundnut in 200,000 households in Malawi, Mozambique, Tanzania, Uganda; of which at least 50% earned by women
- 15-20% increase in income from cultivation of short-duration chickpea and lentil varieties to about 1 million smallholder families, especially women-headed households
- Chickpea, faba bean and lentil harvested mechanically in 2 million ha with 15-20% increase in income in target regions due to reduction in production costs, and 20-25% reduction in labour requirements of farm women involved in chickpea cultivation

**IDO3**  *Nutrition & Health: Increased consumption of healthy grain legumes and products by the poor for a more balanced and nutritious diet, especially among nutritionally vulnerable women and children*

- 10-15% increase in consumption of chickpea and faba bean, 15% of bean in Africa and 40% in Latin America, and 15-20% of lentil in target areas
- 10% higher consumption of groundnut containing low aflatoxin particularly by women and children in India, Vietnam, Malawi, Mozambique, Tanzania, Uganda, Burkina Faso, Ghana, Nigeria, Mali, Senegal and Niger
- 20% higher consumption of lentil containing high iron and zinc content particularly by women and children in India, Bangladesh, Nepal and Ethiopia
- 20% increase in consumption of pigeonpea in poor rural households in India, and 10% in Tanzania, Kenya, Malawi and Uganda, especially by women and children

**IDO4**  *Productivity: Improved productivity of farming systems, especially among smallholder farmers*

- Yields of common bean increase at least 40% among adopters in Latin America and Africa
- Drought tolerant cowpea varieties with 15-20% increase in yield adopted by 10-15% of farmers in target countries and planted in 1.0 million hectares; low-P tolerant cowpea varieties cover at least 500,000 ha in low soil fertility areas of Burkina Faso, Mali, Mozambique, Niger, Nigeria, Senegal and Tanzania.
- Heat tolerant varieties of chickpea, faba bean, lentil and bean cultivated in 1.5 million hectares with 20-25% increase in yield in target regions
- Short-duration chickpea and lentil varieties grown in 500,000 ha in rice-fallows and new niches, improving the cropping system productivity by 20-25% in target regions of South Asia
Adoption of drought tolerant groundnut cultivars provides 10-15% increase in yield in 500,000 ha in India and Vietnam; 200,000 ha in Tanzania, Burkina Faso, Ghana, Nigeria, Mali, Niger, and Senegal; 150,000 ha in Malawi; 100,000 ha in Uganda and Mozambique

Adoption of drought tolerant soybean cultivars will increase grain yield by 15-30% in 50,000 ha in Malawi, 10,000 ha in Mozambique, 15,000 ha in Zambia and 100,000 ha in Nigeria

Adoption of soybean varieties with enhanced biological nitrogen fixation will provide 20-30% increases in grain and biomass yields and add at least 20 kg nitrogen per hectare to soil

Hybrid pigeonpea cultivated on 500,000 ha in target regions in India with an average increase of 20-25% productivity, with an increase in soil organic matter content by 0.2-0.3%

15-20% increase in pigeonpea yields in 200,000 ha in Tanzania, Kenya, Malawi and Uganda

**ID05 Environment: Minimized adverse environmental effects of increased production and intensification of grain legumes**

- An additional 25,000 metric tons of nitrogen from climbing beans, and 25,000 metric tons from improved bush beans
- Cultivation of short-duration foliar diseases resistant groundnut varieties reduces pesticide use by 20-25% in target groundnut producing areas, minimizing environmental contamination by pesticide residues by at least 15%
- Reduction in pesticide use in chickpea and pigeonpea by at least 25% in target regions of Asia
- Reduction of yield losses by 35% in cowpea due to the adoption of IPM innovations based on host plant resistance (including Bt-transgenics), biological control and bio-pesticides, thereby reducing the use of synthetic pesticides by at least 25%
- Increase soil fertility and organic matter content by 0.1-0.2% in the target groundnut areas in SSEA, ESA, WCA

**Theory of change**

Most of the measurable outputs of GrainLegumes are seed-based and therefore have commonalities in their development and dissemination. Historically, seed-based technologies have been relatively easy to transfer to and to be adopted by farmers, with many farmers anxious to experiment with new varieties or hybrids. Exceptions to this route are the GrainLegumes Product Lines on ‘Insect-smart’ cowpea, chickpea, and pigeonpea together with ‘high nitrogen fixing’ crops. Product Line 5 will produce a significant Integrated Pest Management output that will include natural enemies of pests, but this Product Line will have a host plant resistance component that is seed-based. On the other hand, most seed-based approaches will act synergistically with a crop/pest/disease management component, and will also be strengthened by increased market participation that in turn motivates investment in inputs. Similarly Product Line 4 on improved biological nitrogen fixation will include the generation of new inoculants as well as the generation of new varieties. Underlying these interventions is the theory of change strategy of ‘Inclusive Market Orientated Development’ ([http://exploreit.icrisat.org/page/imod/649/123](http://exploreit.icrisat.org/page/imod/649/123), [http://grainlegumes.cgiar.org/how-we-do-it/impact-pathways/](http://grainlegumes.cgiar.org/how-we-do-it/impact-pathways/)) as a priority setting and monitoring tool within the programme. This seeks to identify targets for intervention, and to assess the performance of activities with respect to the aim of improving the livelihood of smallholder farmers as well as the urban and rural poor. This approach is itself under review in order to identify good metrics with which to assess our priority setting, monitoring and evaluation.

**Assumptions related to activities to create outputs**

A number of assumptions are made regarding the potential for the Grain Legumes Research Program to produce the targeted outputs. These include the following.
- Research for poverty-stricken low-potential areas will remain the domain of the public sector at least in next 10 years.
- Adequate genetic diversity exists in germplasm collections to offer significant protection against abiotic stress
- Modern breeding techniques can enhance the breeding of abiotic and biotic stress tolerance as well as nutritional quality.
- Past success in identifying natural enemies of legume pests can be converted into viable IPM systems.
- There is buy-in of partners in the production of the outputs, along with an enabling environment.

A common assumption about dissemination of new legume varieties is that farmers save their own stocks and seldom purchase seed, and that this is a disincentive to the private sector to produce and stock legume seed. Undoubtedly this has been a barrier to the rapid dissemination and the “reach” of improved legume varieties. However, this has also stimulated a more creative and diversified approach to legume seed production and dissemination systems. Among the multiple approaches tested, several scenarios for the marketing of small quantities of seed at economical prices (e.g., small seed packets) proved promising especially in reaching women who in particular are seldom in a position to afford large quantities at one time. Being able to experiment with new varieties at minimal risk motivated thousands of farmers to purchase seed packets for as little as the cost of a cup of tea. In turn some seed producers were motivated to enter the legume seed business, selling at a small unit price but at a higher per weight price. Mapping access by farmers to seed outlets will facilitate putting improved and high-quality seed within reach of smallholder farmers. Some of the CRP seed-based products are designed to augment total food production and availability, and are targeted to producers with more resources (e.g., hybrid pigeonpea, herbicide resistant and/or machine harvestable varieties), at least in the near term. Some of these technologies implicitly will be accompanied by changes in input use or machinery, with the expectation that input providers will respond to this opportunity and for women farmers drudgery may also be reduced.

One critical component of success has been to substitute the vertical model of the impact pathway (researchers to national partners to extension agents and seed producers) for an interactive model with feedback loops back and forth between farmers, traders, researchers, and seed producers. This links supply and demand, and has permitted the development of business and professional relationships whereby users and suppliers of seed (or other technologies) enter into agreements that facilitate the flow of seed. These relationships should be nurtured to evolve into “innovation platforms”. Other technologies benefit from other sorts of person-to-person communication such as farmer field schools, for which a “gender sensitive training of trainers” strategy can serve for scaling up. These considerations suggest the requirement for GrainLegumes to interact directly with development agencies, which itself could be monitored and evaluated.

Assumptions and risks to attain “reach”
- Quality breeder and foundation seed can be produced in adequate quantities.
- While small seed packs are a low risk option for farmers, especially women, that permits them to experiment with new varieties or hybrids, private seed companies may need some support to participate in this strategy.
- Multiple approaches encouraged by the public sector will be needed to expand dissemination.
- Novel agronomic practices that require capital investment will find slower adoption but this will be facilitated by marketable varieties.

While there are many behavioural changes in terms of seed purchase, crop management, etc., the essential behaviour change at all levels (farmers, seed producers, input suppliers, and policy makers) needs to be a new attitude toward legumes. Farmers often plant a legume only after other crops are already established. As noted above, many seed producers see little future in legume seed. Policy
makers fix their attention on volumes of food that normally proceed from cereals, and not on quality. All must be encouraged to consider legumes to be an indispensable component of the diet and of the farming system. An awareness of their nutritional value and health effects is an important part of this message, but a growing economic value driven by more effective markets will be the most effective tool for this, combined with a more effective communication strategy. The protein quality of a food depends on its digestibility and the concentration of essential amino acids. The relatively high lysine concentration in legumes complements cereals with low lysine concentrations. Combining legumes and cereals in the diet contributes to better overall dietary protein quality.

**Assumptions to attain change in capacity and behaviour**

- Dissemination with participation gives farmers exposure to new varieties with greater market potential and leads to behaviour change following the IMOD strategy (http://exploreit.icrisat.org/page/imod/649/123).
- Farmers with modest-to-good capital and market access will adopt crop management techniques, especially when the variety lends itself to higher technology.
- Enhanced markets will attract the attention of farmers, the private sector, and policy makers, and will raise the profile of all these actors.

With the change in behaviour described above, support for legumes at all levels should be enhanced and the enabling environment greatly facilitated.

**Assumptions about the enabling environment**

- At least some seed companies will be induced to distribute and sell small seed packs, while others will eventually respond to the opportunity afforded by a more technical production system.
- Extension services, especially those sponsored by NGOs, will help reach the poorest of the poor.

**Gender research**

The gender research strategy of GrainLegumes is described in a separate document. As a component of the ‘theory of change’ in relation to the establishment of research priorities we need to determine how to use gender research in priority setting. Strategic gender research will be undertaken to orient planning and priority setting by conducting diagnostic research to identify research targets that can have desired gender disaggregated outcomes. For example, in mungbean, the research target of erect plant habit and synchronous maturing varieties, has led to a reduced frequency of harvesting (from 5 to 2), leading to savings in women’s labour in Northern India, this is closely related to objectives identified in phase one. Outputs will inform other areas of research of the gender-related constraints and opportunities faced by women along the value chain including technology access and adoption; the development of strategies to address gender inequalities in access to and control over resources and services; and identification of aspects of technology design needed for research to be responsive to gender differences in adoption and the distribution of benefits from new legume technology.

Post hoc analysis will determine the impact of research in gender disaggregated statistics.

**Caveats**

GrainLegumes will achieve the IDOs and targets described above through numerous impact pathways and theories of change that will vary in detail depending on the crop, technology innovation, value chain and region being targeted. Such specificities are under draft and the targets described above are preliminary attempts at making such definitions and these need verification as to the feasibility of measuring, validating and attributing these to actions of GrainLegumes. In this document, we have presented an overall picture of the impact pathway and theory of change that leads from the research outputs from each Product Line to the behavioural and capacity change expected among targeted immediate beneficiaries, ultimately leading to the desired set of Intermediate Development Outcomes and System Level Outcomes.

The Intermediate Development Outcomes are external to, but supported by our research. The connection between IDOs and System Level Outcomes (or Sustainable Development Goals)
therefore needs to be explained; as does the connection between our research and the achievement of the IDOs as has been attempted above. The efforts at making common IDOs across CRPs makes sense for a portfolio of interconnected research programmes with the same, or similar, overall objectives. However, we need to be aware that the connection between a given IDO and SLO may differ between research programmes. We therefore need to be careful in not reading too much into the common IDOs while recognising the utility of a common framework.

The argument against dispensing with IDOs, and explaining directly how our targets contribute to SLOs, is that the IDOs are more easily understood in relation to research activities and can contribute to more than one SLO.

At the level below IDOs we have research outputs that contribute progress towards our targets that represent specific components of an IDO. What we can enumerate or quantify are our research outputs and from these estimate a contribution to the progress towards an IDO. This estimate seems very difficult to obtain and interpret. For example, if we improve the value (nutritional, financial ...) of a crop, through the introduction of some characteristic to an improved variety, we can estimate the contribution of this improvement with respect to an unimproved variety. But what if there is also an improvement in the seed certification and marketing that improves the penetration of the improved variety to the farmers? What if there is more than one improvement? These complexities need to be understood before targets are considered as quantitative (and comparative) measures of progress rather than broad indicators. Some of the contributions of outputs to outcomes may be non-additive; some may be synergistic and others interdependent further emphasising the need for caution in treating targets and IDOs as metric parameters.